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INSTRUCTION BOOK

MODEL 91D

RF VOLTMETER

BOONTON ELECTRONICS CORPORATION

Serial No._____

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Boonton *ELECTRONICS* Corporation

738 SPEEDWELL AVENUE, MORRIS PLAINS, NEW JERSEY, U. S. A.

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SECTION 1

SPECIFICATIONS

Measurement Range	300 microvolts to 3 volts.
Full Scale Ranges	Full scale readings of 0.001 volt to 3 volts in a 1,3,10 sequence in 8 ranges.
Decibel Range	80 db in 8 ranges.
Frequency Range	10 Kc to 1200 Mc.
Accuracy	3% of full scale;50 Kc to 50 Mc. 5% of full scale;20 Kc to 200 Mc. 10% of full scale;10 Kc to 1200 Mc.
Input Impedance	See Figure 1.
DC Output	Linear. At least 1.0 volt across 1,000 ohms.
Meter Calibration	Linear distribution: 0.9 to 3.2 and 2.8 to 10. Decibels:0 to -11.
Tube Complement	1 - BEC 525,001(12AX7 special) 1 - 12AX7 1 - 7199 1 - 6X4 1 - 0A2 1 - 12AT7
Power Requirements	105 to 125 volts, 58 to 62 cps, 40 watts.
Probe Accessories	91-13A Probe Tip, 10 Kc to 250 Mc.
	91-14A Type N Tee Adapter, 10 Kc to 1200 Mc. VSWR less than 1.15 to 1000 Mc and less than 1.2 to 1200 Mc.
	91-15A 50 ohm termination
	91-16A Unterminated Type N Adapter 10 Kc to 100 Mc (to 400 Mc when fed from a 50Ω source in an electrically short system).
	91-7B 100:1 Voltage Divider, 50 Kc to 250 Mc.

SECTION 2

GENERAL DESCRIPTION

The 91D RF Voltmeter is a sensitive instrument for the measurement of voltages of 300 microvolts to 3 volts spanning a wide frequency range of 10 kilocycles to 1200 megacycles. In addition to measuring voltage levels in a diversity of rf circuits, the instrument has application for many associated tests. Such measurements include: the frequency response of both active and passive networks, i.e., amplifiers and filters; VSWR and return loss on transmission lines and attendant systems; attenuation and insertion loss of rf attenuators; and high frequency parameters of transistors. With true rms response below 0.03 volt (up to 3 volts with the 91-7B, 100:1 Divider), harmonic distortion of rf waveforms and wide band noise can also be measured.

The instrument is also useful as an rf null detector for bridge measurements and analogous techniques.

A complete set of accessories with a case are supplied with each instrument.

The probe tip and companion ground clip are useful for direct measurements to approximately 100 megacycles. Above 100 megacycles the probe may be used directly without the tip but connecting leads must be extremely short to avoid resonant effects. In the special case where it is possible to connect the probe directly to the voltage source, the specified tolerance is maintained to a least 1200 megacycles. The impracticability of such a connection, however, precludes our assuring the accuracy of the 91D RF Voltmeter above 250 megacycles without the use of the 91-14A Type N Tee Adapter and the 91-15A 50 ohm Termination.

The 91-12A probe with its full-wave crystal detecting circuit produces a true rms response without turnover or harmonic errors for all voltage levels below 0.03 volt, gradually changing to peak-to-peak reading (calibrated in rms) at the higher levels. The probe with the probe tip has a shunt capacitance of approximately 2.5 pf at levels of 0.5 volt or higher, increasing slightly at levels of 0.1 volt or less. The shunt resistance component is also a variable factor, depending on the voltage and frequency. (See Figure 1).

The use of the 91-7B 100:1 Voltage Divider extends the voltage range to 300 volts (from 50 Kc to 250 Mc) and provides a true rms response up to 3.0 volts.

SECTION 3

OPERATION

3.1 General

This section should be read before using the instrument. It contains information necessary for proper operation of the 91D RF Voltmeter.

3.2 Controls and Connectors

a. ON - This switch energizes the power transformer when the a-c cord and plug is connected to the proper power source as indicated on the Serial Number nameplate.

b. RANGE - FULL SCALE - VOLTS/ DB - This range switch adjusts the amplifier gain, and/or the input attenuator, as well as the proper linearizing network for the selected voltage range.

c. PRESS TO BALANCE - This control introduces a small d-c voltage into the probe circuit to balance out minute thermal voltages that develop in low level d-c circuits. When the control is pushed toward the instrument panel, the meter circuit is altered to permit an upscale reading of the residual noise. The control should then be adjusted for minimum meter reading. The control knob must be released without turning.

d. OUTPUT TERMINALS - Two posts marked + and - are provided for external instrumentation. The voltage available from these terminals is a linear function of the input voltage and should not be less than 1.0 volt for a full scale meter reading. The output impedance is low and nominally less than 600 ohms.

e. OUTPUT ZERO - This control provides a zero adjustment for the d-c voltage at the output terminals prior to applying r-f voltage to the probe.

f. PROBE - The probe cable connects to the instrument through this jack. It is imperative that the knurled ferrule nut of the probe cable connector be tightened.

3.3 Initial Procedure

a. Before the 91D is turned on, the meter pointer should be examined to see that it rests on the zero reference line. If necessary, an adjustment may be made with the mechanical zero set on the meter.

b. Turn the instrument on and allow a warm-up period of 10 to 15 minutes.

c. Connect the probe to the jack marked PROBE. The knurled ferrule nut must be tight. Connect any of the coaxial adapters to the probe. Do not use the probe tip for this particular test.

d. Turn the RANGE-FULL SCALE switch to the 0.001 volt position and adjust the PRESS TO BALANCE control for a minimum reading. The knob for this control should be pushed toward the panel before an adjustment is made. See Section 3.2c.

3.4 Low Frequency Measurements

Frequency within the range of 10 kilocycles to about 10 megacycles may be considered low frequencies for 91D RF Voltmeter applications. Any of the adapters supplied with the instrument may be used in this spectrum (Exception: the 91-7B 100:1 Voltage Divider has a lower frequency limit of 50 kilocycles).

In general, the high impedance probe may be used with a ground lead of 3 to 6 inches without introducting measuring errors. In the presence of strong fields, however, it is recommended that where possible the 91-16A Unterminated N Adapter be used.

3.5 High Frequency Measurements

In the frequency domain of 10 megacycles to 200 megacycles it is permissible to use the probe tip and a conventional ground clip at the lower frequencies whereas measurements at the upper frequencies of this band require special techniques.

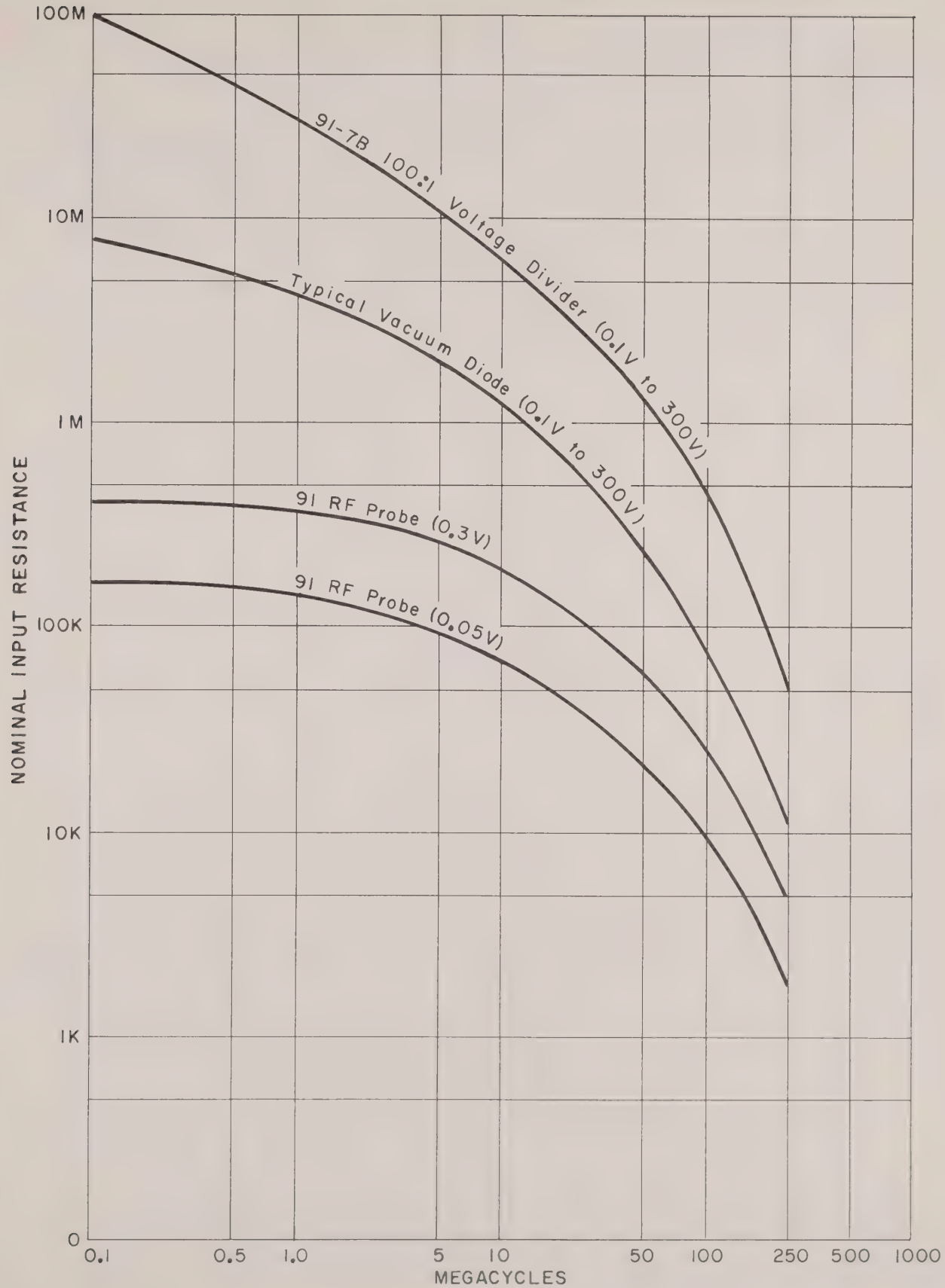
Above approximately 100 megacycles the inductance of any conductor at the input of the probe (either the ground lead or center conductor) may cause an appreciable error in the indicated voltage owing to partial resonance of the lead inductance and input capacitance of the probe. Moreover, any impedance in the ground lead may develop an error voltage owing to circulating currents between instruments. The importance of low impedance connections at high frequencies cannot be overemphasized.

For high impedance measurements at frequencies above 100 megacycles the probe should be connected without leads directly to the voltage source. The input impedance of the probe will have negligible effect upon low impedance circuits, i.e., less than 200 to 300 ohms. An example of such a connection is shown in Figure 2.

High impedance circuits in the range of 50 to 200 megacycles usually take the form of a parallel resonant circuit. Connecting the 91-12A probe to this type of circuit may have a twofold effect: (1) the input capacitance of the probe will detune the circuit, and (2) the resistive component of the input impedance will produce some loading across the circuit.

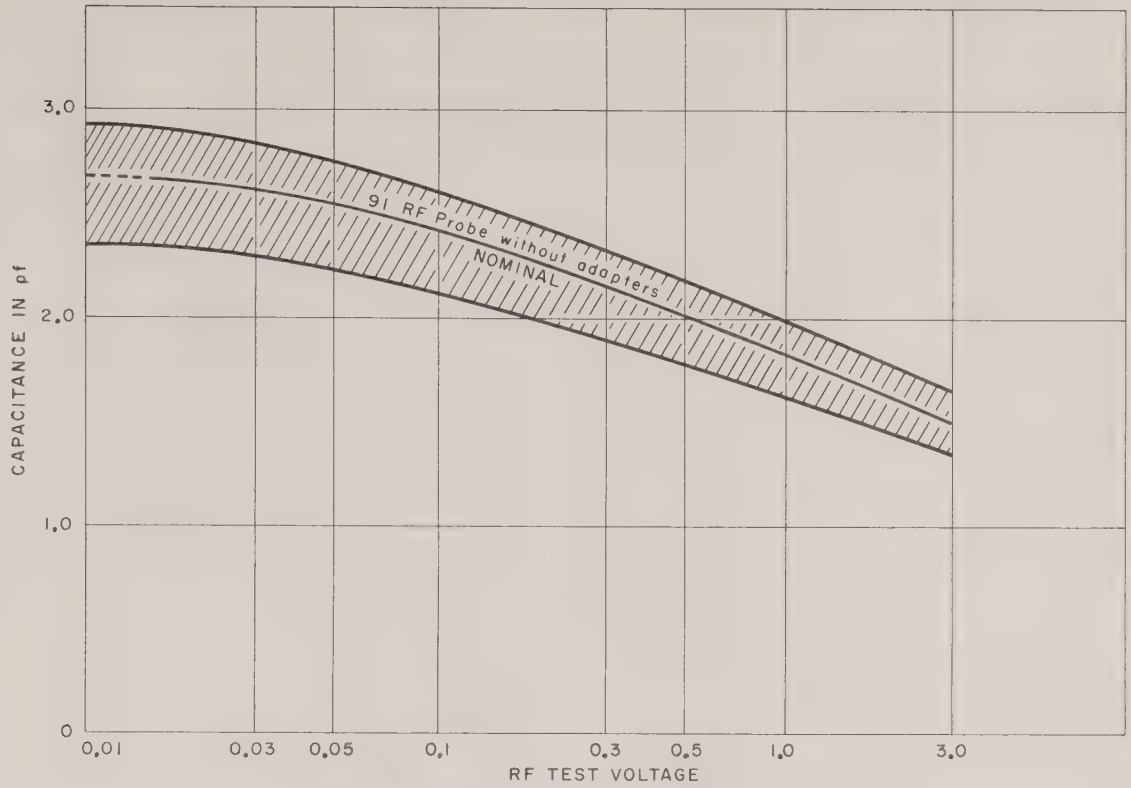
If the circuit to which the probe is connected is tuned by a variable capacitor, the correction for the first effect is to reduce the capacitance of the circuit by an amount equal to that added by the probe (2 to 3 pf). Correction for the loading effect is not as simple. The input resistance of the probe is to some extent a function of the voltage level applied to the probe. Figure 1 gives nominal values of input resistance **vs.** frequency for three voltage domains.

If the voltage to be measured exceeds 30 millivolts, the 91-7B 100:1 Voltage Divider is recommended for high impedance measurements at frequencies up to 250 megacycles. This adapter connects directly to the probe and may be introduced into the circuit in the same manner as suggested for the probe in Figure 2. The resistive loading presented by the 91-7B adapter is in the order of 100 megohms at 0.1 megacycles, decreasing to 0.1 megohm at 200 megacycles. Provided the input capacitance of about 2.5 pf exhibited by this adapter can be negated by retuning the circuit, the loading in most r-f circuits will be negligible.


100M
10M
1M
100K
10K
1K
0
NOMINAL INPUT RESISTANCE
91-7B 100:1 Voltage Divider (0.1V to 300V)
Typical Vacuum Diode (0.1V to 300V)
91 RF Probe (0.3V)
91 RF Probe (0.05V)
0.1
0.5
1.0
5
10
50
100
250
500
1000
MEGACYCLES

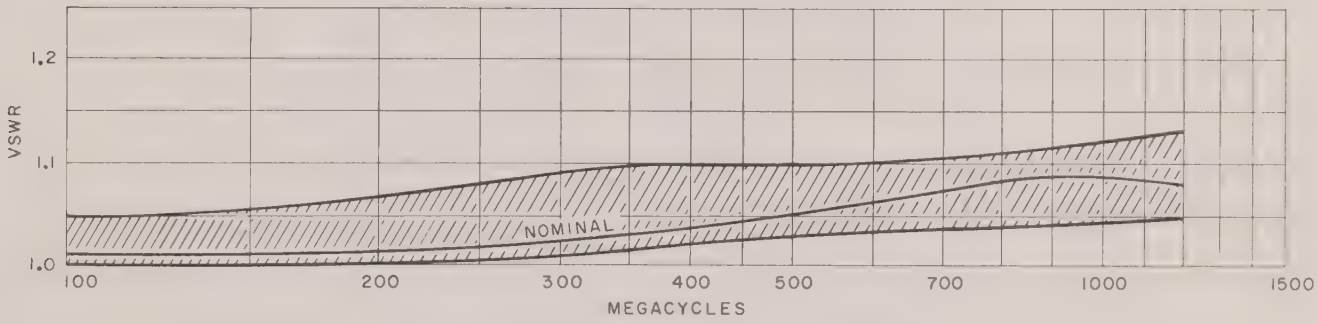
91D
a

Fig 1a



INPUT CAPACITANCE vs TEST LEVEL
(measured at 10 Mc)

Fig 1b



TYPICAL VSWR OF 91-12A RF PROBE
with 91-14A Type "N" Tee Adapter
terminated in a 91-15A 50 Ohm Termination

Fig 1c

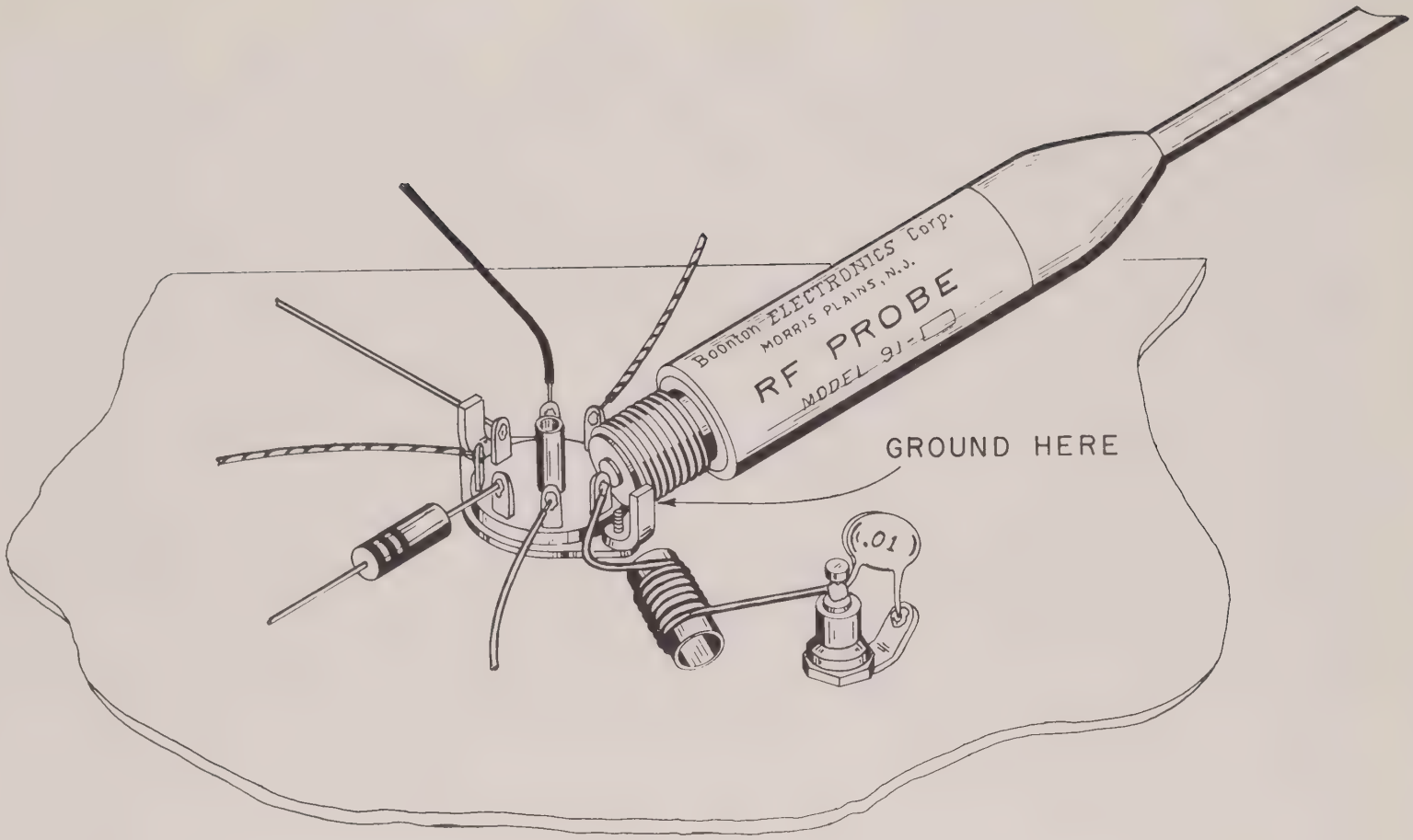

Boonton ELECTRONICS Corp.
MORRIS PLAINS, N.J.
RF PROBE
MODEL 91-
GROUND HERE
.01

Fig. 2

An additional benefit which obtains with the use of the 100:1 Voltage Divider is an extension of the true rms operating region to 3.0 volts.

3.6 UHF Measurements

Voltage measurements are not recommended above 250 megacycles without the use of the 91-14A Type N Tee Adapter and companion 91-15A 50 ohm Termination. Measurements should preferably be made in electrically short 50 ohm systems ($\ell < 0.1\lambda$). If an electrically long transmission line ($> 0.25\lambda$) is interposed between the source and the 91-14A Tee Adapter, the return-loss of the source impedance should be moderately high (say, 20 db, or more) to reduce the standing waves and attendant errors. The worst condition will exist with a poorly matched source impedance. Under this condition, the measured voltage at the terminus of a long line will be a function of the reflection coefficient, hence the VSWR, of the terminating resistor. In the case of the 91-14A and 91-15A, the maximum VSWR is 1.15 up to 1000 megacycles and less than 1.2 to 1200 megacycles.

It is important that the 91-14A Type N Tee Adapter be used in the direction shown in Figure 3. For certain measurements it may be necessary to interpose a length of cable between the Tee Adapter and the Termination. If such a connection is made, the cable selected should be of good quality with a characteristic impedance of 50 ohms.

Provision for disconnecting the 50 ohm termination permits the substitution of a test termination, or the interposition of the tee and probe at any convenient place in a transmission line system.

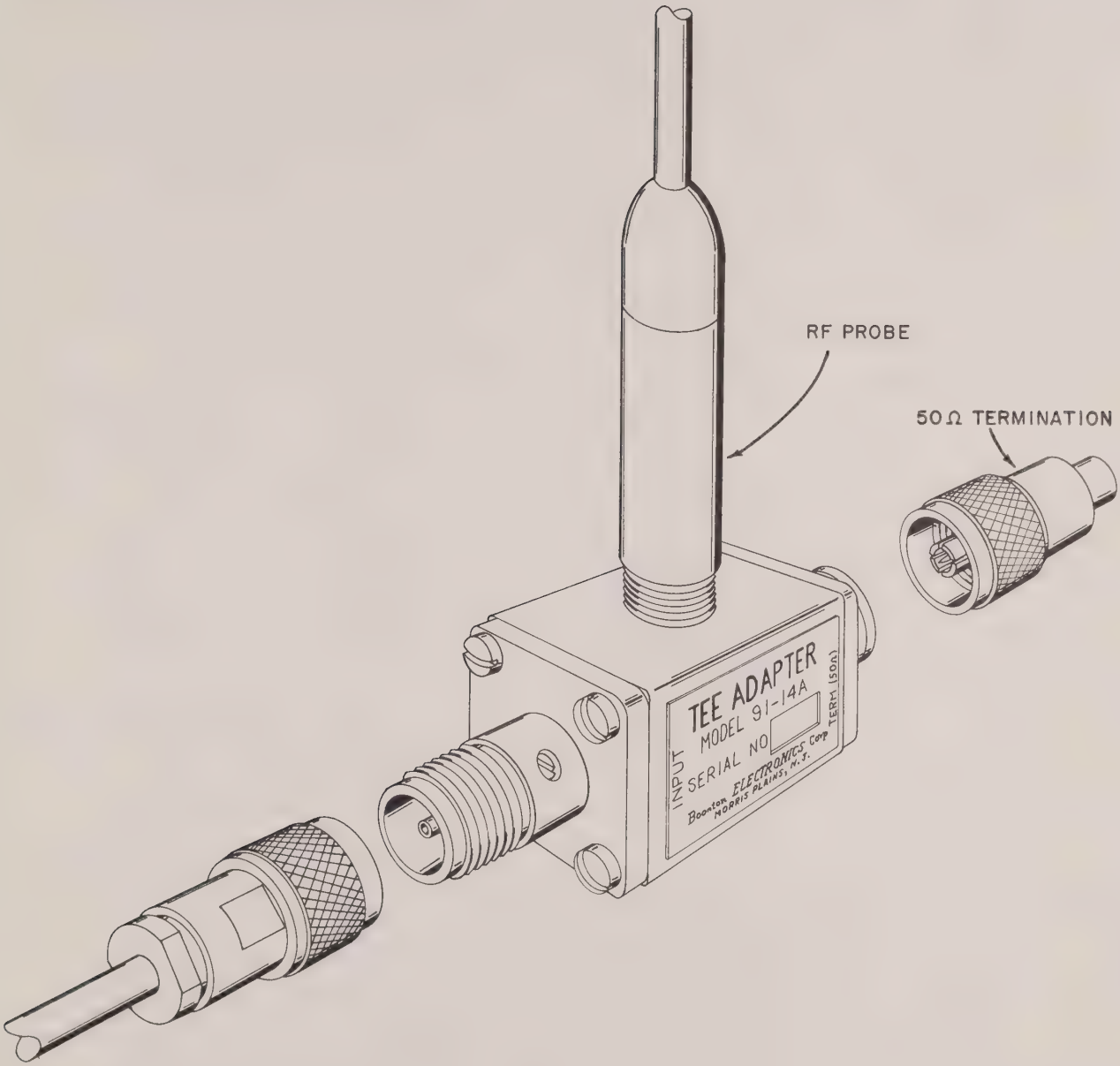

RF PROBE
50Ω TERMINATION
INPUT
TEE ADAPTER
MODEL 91-14A
SERIAL NO
TERM (50Ω)
Boonton ELECTRONICS Corp
MORRIS PLAINS, N.J.

Fig. 3

3.7 High Voltage Measurements

The 91-7B 100:1 Voltage Divider permits the measurement of voltage above 3 volts in the frequency range of 50 Kc to 250 Mc. At these frequencies a maximum voltage of 300 volts may be measured with the divider. The d-c voltage rating of the input capacitor, however, is 1000 volts, and the crest voltage of combined d-c and r-f should, therefore, be kept below this value.

As previously mentioned, the 91-7B Adapter extends the true rms range of the RF Voltmeter from 30 millivolts (without the adapter) to 3.0 volts.

High voltage measurements up to 250 Mc can be made using the 100:1 Voltage Divider with either the high impedance probe tip, or by connecting the divider to the 91-14A Type Tee Adapter. The VSWR of the terminated tee adapter under this condition will not exceed 1.15 at frequencies up to 250 Mc.

3.8 Precautions

For long instrument life and optimum performance a few precautions should be observed when using the 91D RF Voltmeter.

3.8.1 Maximum Input Voltage-RF

To secure the many desirable properties of the special diodes used in the voltmeter probe, the peak reverse voltage rating cannot be made greater than about 30 volts with the present state of the art. This limits the maximum rms input level to approximately 9 volts; a margin of 3 to 1 above the maximum range of the instrument.

A simple precaution which will reduce the chance of diode burn-out is to use the 91-7B 100:1 Voltage Divider when working with r-f voltages above, say 100 millivolts, at frequencies from 50 Kc to 250 Mc. In addition the advantages outlined in Section 3.7 also obtain.

3.8.2 Maximum Input Voltage - DC

RF Voltages, superimposed on d-c potentials of up to 400 volts, may be measured without damaging the probe diodes. Higher d-c protection (to 1000V) may be obtained with the use of the 91-7B 100:1 Voltage Divider with an attendant reduction in sensitivity. Although protection of the probe for d-c voltages up to 400 volts is provided in the design, pulsing of the probe with higher d-c voltage may damage the diodes. Wherever possible the circuit of Figure 4 should be used to remove the d-c component prior to measuring the r-f voltage.

3.8.3 High Intensity, Low Frequency Fields

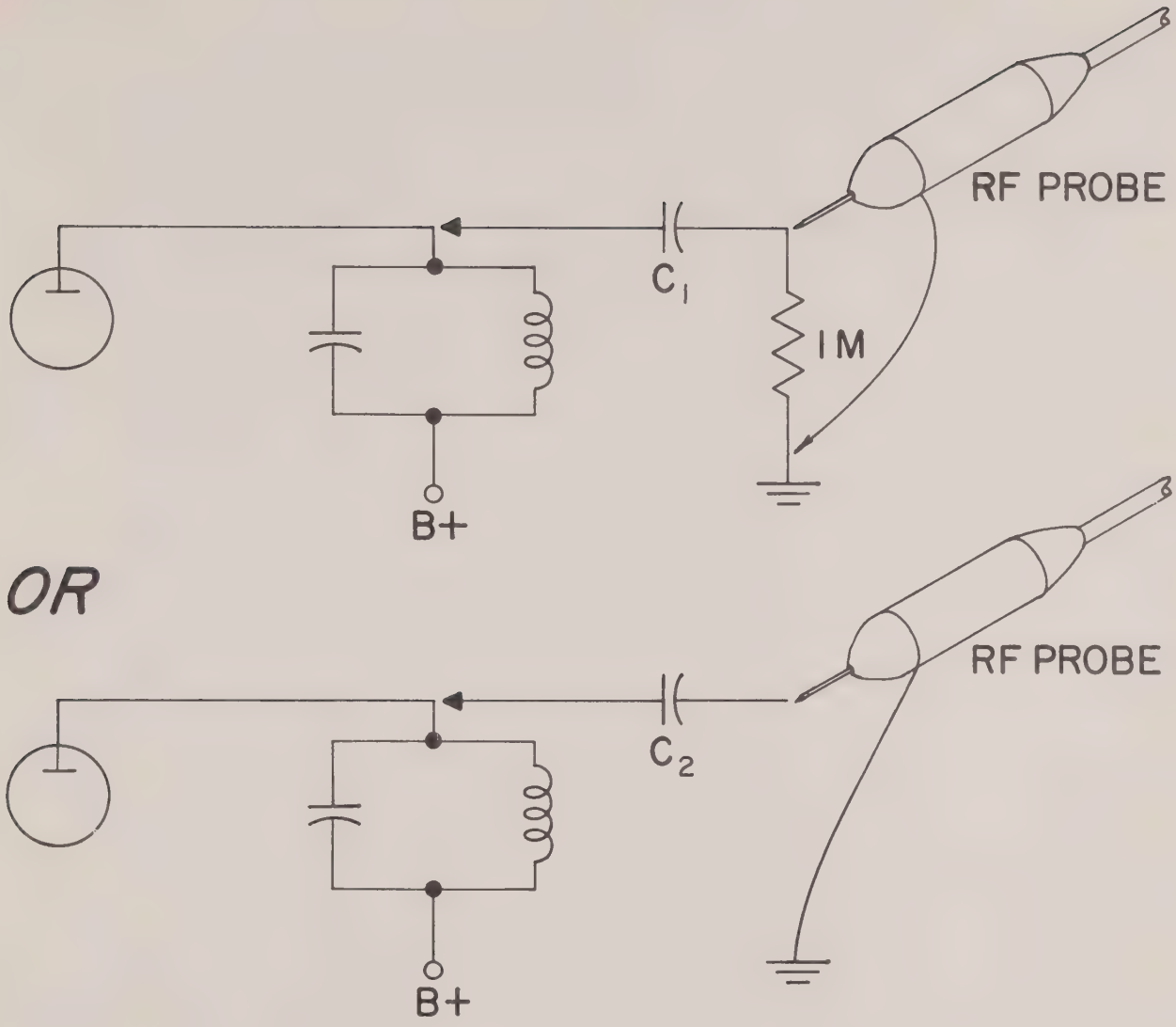
The amplifier section of the 91D RF Voltmeter has a maximum gain at 60 cps of approximately 120 db. Although the instrument incorporates both magnetic and electrostatic shielding, the voltmeter cannot be expected to function properly on its more sensitive ranges in the proximity of strong 60 cycle fields.

One source of considerable interference, common in many laboratories, is the magnetic type of 60 cycle line voltage stabilizer. The 91D RF Voltmeter should be operated at a suitable distance from such devices as well as other devices which generate high intensity fields.

It is suggested when using the RF Voltmeter on its most sensitive range in the proximity of any a-c line operated equipment, that the adjacent equipment be momentarily de-energized to note its effect upon the indication of the voltmeter.

3.8.4 High Intensity, High Frequency Fields

The measurement of low level r-f voltages in the presence of high level, high frequency fields requires excellent shielding if gross errors are to be avoided. In particular, the use of the probe tip and companion ground clip is precluded.



C_1 should be a sensible short circuit at the measuring frequency.

C_2 should be 100 pf or less.

METHODS FOR PROBE ISOLATION FOR HIGH DC VOLTAGES

Fig 4

91D
a

Moreover, the balancing operation required for the most sensitive range (1 millivolt) should be performed with the probe connected to the circuit which should be temporarily disabled.

It is likely that such measurements will require special fixtures and jigs to ensure accurate measurements.

SECTION 4

TECHNICAL DESCRIPTION

4.1 General

The 91D RF Voltmeter employs a miniature, low capacitance probe which converts the r-f voltage to a proportional d-c potential. This d-c voltage is in turn converted to a 60 cycle a-c signal by a special low noise mechanical chopper. A selective amplifier follows the chopper and raises the 60 cycle level to a value sufficient for rectification, linearization, and metering. The DC Output Cathode Follower is also fed from this point. Additional circuitry is provided to spread the useful portion of the meter scale over a larger-than-normal percentage of the pointer range for greater readability.

4.2 Probe

The RF Probe contains a blocking capacitor and two high frequency diodes connected for full-wave rectification. Adequate by-passing and resistive isolation is included. The probe is connected to the voltmeter cabinet by means of a flexible low noise cable and connector.

Owing to the possibility of degradation of performance by replacing diodes in the probe without complete facilities for calibrating the instrument, components in the probe have not been shown on the schematic.

4.3 Chopper Modulator

The SPDT mechanical chopper has break-before-make contacts and operates from the 6.3 volt, 60 cycle winding of the power transformer. A low pass RC filter ahead of the chopper suppresses any 60 cycle voltage which may be introduced through the probe. After using the voltmeter on the 1 or 3 volt range, the capacitors in this filter will require 40 to 60 seconds to discharge sufficiently to permit operation on the 1 millivolt range.

A resistive attenuator appears between the output of the chopper and the input of the amplifier. The attenuator has five adjustments which are described in Section 5.

4.4 Amplifier

The amplifier in the 91D raises the signal level from the chopper to a level adequate for converting the square-law response from the probe (for measured voltages of less than 30 millivolts) to a linear direct current for the meter. As the measured voltage increases the extent of the conversion is reduced.

The BEC 525,001 (12AX7) Preamplifier is contained within the shielded box attached to the front subpanel. The box also houses the input attenuator and switching for feedback control in the preamplifier, as well as the chopper and its circuitry.

The preamplifier is followed by a second 12AX7 which drives the selective output amplifier.

The output stages consist of a combination pentode-triode tube (type 7199). The pentode operates as a normal amplifier and is coupled to the triode which functions principally as a cathode follower. A small plate load resistor, however, provides negative feedback to the cathode of the pentode. In addition, two feedback paths are taken from the triode cathode to the grid of the pentode. One circuit consists of a simple parallel RC path, the other is a twin-tee null network tuned to 60∿.

These circuits produce an output amplifier which is broadly tuned to 60∿ having approximately 18 db of attenuation at 120 ∿. The output impedance of the cathode follower is sufficiently low to drive the rectifier circuit without appreciable distortion.

The combination of regulated d-c heater and plate voltage for the two 12AX7's as well as negative feedback around all stages makes the instrument calibration sensibly independant of line voltage changes from 105 to 125 volts.

4.5 Rectifier and Meter Circuit

The meter rectifier is a half-wave voltage doubler. The d-c voltage derived from this circuit is applied to a network of stabistors (voltage sensitive resistors) and adjustable resistors which are employed to convert the amplified non-linear response of the r-f probe to a linear current for the indicating meter.

4.6 DC Output Cathode Follower

This stage is provided to drive external recording equipment. The output voltage at the front panel terminals should be at least 1.0 volt (relative to full scale) when connected to a 1000 ohm load.

Although the d-c output voltage is a direct linear function of the r-f input voltage (as opposed to the expanded, but equally divided meter divisions), the d-c output is usable only when the meter is on some portion of its calibrated range.

4.7 Power Supply

A conventional full-wave rectifier, using a 6X4 vacuum tube, furnishes the necessary high voltage d-c potentials for the instrument. A portion of this voltage is regulated with an OA2 gas discharge tube for the plate voltage of the first and second amplifier tubes.

The heater voltage for these same stages is rectified and regulated using a selenium rectifier (full-wave bridge) and a germanium pnp power transistor.

Heater voltage for the output stage and the DC Cathode Follower is derived from the 6.3 volt transformer winding.

SECTION 5

MAINTENANCE

5.1 Periodic Checking

The Model 91D Voltmeter is designed to give long periods of service without maintenance when operated in accordance with the instructions in this book. It is recommended, however, that the instrument be checked periodically using reliable standards to ensure against errors resulting from deterioration of either the tubes or the chopper. To make these tests, it is necessary to have a signal source of 200Kc to 500Kc with less than 1% distortion at levels up to 3 volts across 50 ohms. A suitable attenuator to adjust this level between 300 microvolts. and 3 volts and a precision electronic voltmeter, such as the Hewlett Packard Model 400H, to monitor the signal source. The high frequency response of the 91D may be checked with laboratory a-c to d-c transfer standards. The Ballantine Model 440 Micro-potentiometer is recommended for this purpose.

5.2 Calibration Precautions

To check the calibration accuracy on an RF Voltmeter having the sensitivity and bandwidth of the Model 91D, it is necessary to take precautions to avoid errors resulting from stray pick-up voltages. (See paragraphs 3.8.3. and 3.8.4). A well shielded signal source must be used in conjunction with coaxial connections to both the Model 91D and the standard reference meter. Even with such equipment it is sometimes possible for the reference meter to pick up stray RF signals and feed them to the probe. Check for this condition by disconnecting the standard meter and noting a change in level.

5.3 Calibration Check Procedure

Each range of the 91D should be checked at a voltage representing 90% of full scale value. If these check points agree within ± 2% of the standard, it is recommended that no adjustment be made. If the check points deviate by more than ± 2% from the standard, the calibration adjustment procedure as outlined in paragraph 5.5 should be followed. If it is impossible to adjust the instrument to within 1% of the standard meter, it is recommended that a trouble shooting procedure be followed as outlined in paragraph 5.4.

5.4 Trouble Shooting Procedure

5.4.1 Case Removal

The instrument may be removed from its case after first removing the two screws located at the back of the case (near the bottom) and the four screws located on the sides of the case near the front.

5.4.2 Tube Replacement

If the tube V1 should become weak or noisy, it should be replaced with BEC 525,001 or a commercial low noise 12AX7 which has low microphonism and meets the requirements of paragraph 3.3.4. The Telefunken ECC83/12AX7 has consistently met these requirements. After replacing defective tubes recheck the calibration as outlined in paragraph 5.3 and if necessary adjust the instrument as described in paragraph 5.5.

5.4.3 Chopper Replacement

Poor chopper performance is usually evidenced by an abnormally high meter indication on the 0.001 volt range for zero input voltage. (See Section 3.8.3 and 3.8.4). The meter pointer should drop to the zero reference line after proper adjustment of the PRESS TO BALANCE control. If the meter cannot be zeroed, a replacement chopper should be tried.

If the new chopper does not correct the difficulty, replace the original chopper. If a new chopper does correct the difficulty, the calibration should be rechecked and adjusted, if necessary, after a run-in period of an hour or two.

5.4.4 Voltage and Resistance Tests

After determining that the trouble cannot be cured by replacement of tubes or chopper, as described previously, it is advisable to make a systematic check of AC voltage, DC voltage and resistance at each socket pin. Table I shows the nominal AC and DC voltages to ground from each socket pin number. Table II shows the nominal resistance values expected for each point. Large or erratic deviations from the listed values of voltage or resistance will serve as a clue in tracking down a faulty component. Once the trouble has been found and corrected, the calibration must be rechecked and readjusted as outlined in paragraph 5.3 and paragraph 5.5.

5.5 Calibration Adjustment Procedure

Before making any calibration adjustment it is essential to provide the necessary reference standards as described in paragraph 5.1 and take all precautions as outlined in paragraph 5.2. The calibration adjustment shall then be made as outlined in the following procedure.

5.5.1 Equipment Required

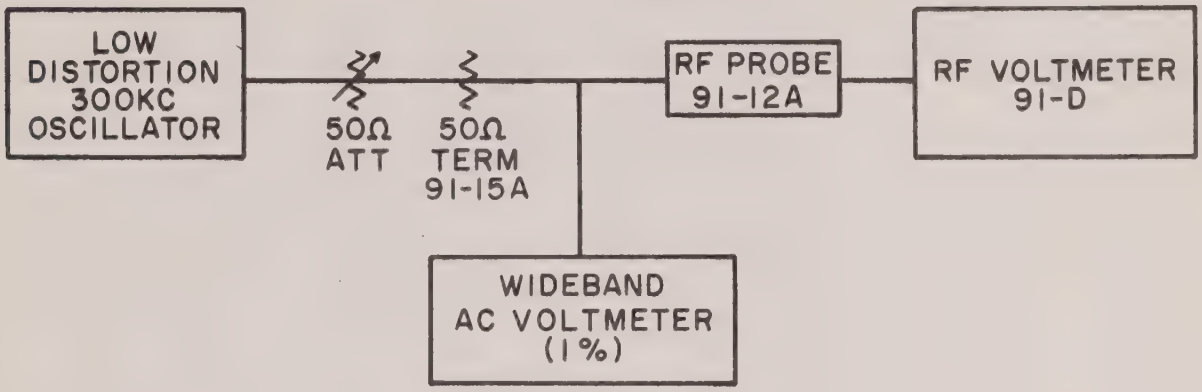
a. A low distortion ($< 1\%$) oscillator (200 to 500 Kc) capable of generating 3 volts across 50 Ω.

b. A wideband a-c voltmeter with an accuracy of 1% or better, with a range of 300 microvolts to 3 volts.

c. A 50Ω r-f attenuator with sufficient adjustment in conjunction with the oscillator level control, to permit reduction of the level to 300 microvolts.

5.5.2 Calibration Set-up

All connections on the following block diagram should be made with coaxial cable and connectors.



5.5.2 Preliminary adjustment

a. Connect a high impedance a-c voltmeter (through a blocking capacitor if none is provided internally) to the cathode of V-3b (yellow lead on the top terminal board - see Figure 5).

b. With zero input to the 91D set the RANGE switch to 0.001 volt and adjust the PRESS TO BALANCE control for minimum indication on the meter.

c. Apply a 0.001 volt signal to the probe and adjust R47 (GAIN) for a reading of 13 volts at the cathode of V-3b.

d. Turn the RANGE switch to the 0.01 volt position and increase the input level to 0.01 volt.

e. Adjust the ADJ 0.01 (R37), located on the bottom of the pre-amp housing, for a meter reading of 13 volts at the cathode of V-3b.

5.5.4 Calibration

Table I describes the procedure for calibrating each range of the 91D, provided the steps of paragraph 5.5.3 have been followed.

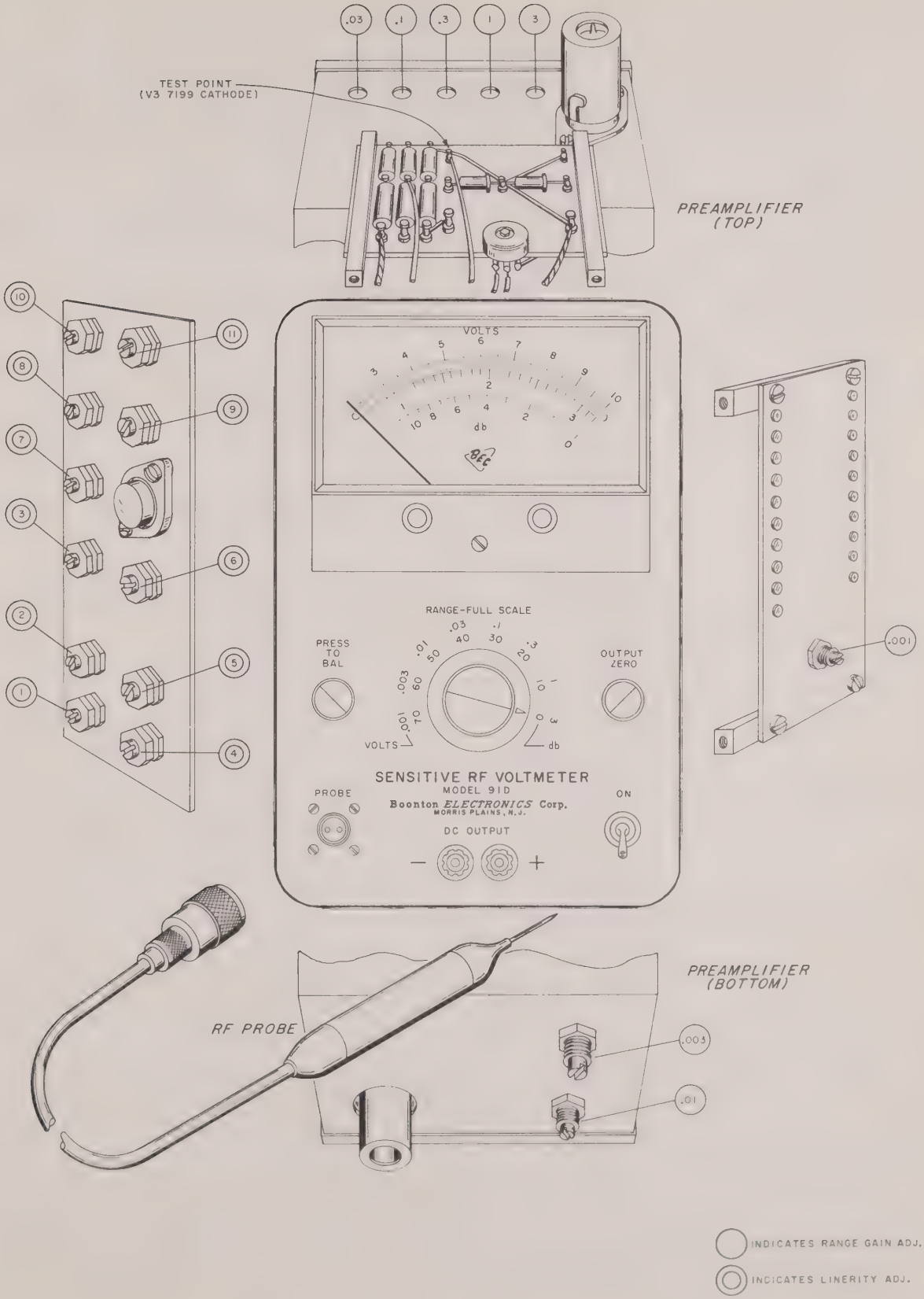

.03
.1
.3
1
3
TEST POINT
(V3 7199 CATHODE)
PREAMPLIFIER
(TOP)
VOLTS
db
RANGE-FULL SCALE
PRESS
TO
BAL
OUTPUT
ZERO
VOLTS
db
SENSITIVE RF VOLTMETER
MODEL 91D
Boonton ELECTRONICS Corp.
MORRIS PLAINS, N.J.
PROBE
ON
DC OUTPUT
RF PROBE
PREAMPLIFIER
(BOTTOM)
.001
.003
.01
INDICATES RANGE GAIN ADJ.
INDICATES LINERITY ADJ.

Fig. 5

TABLE I

STEP	VOLTAGE APPLIED	RANGE SETTING	ADJUST CONTROL NO.	TO READ	COMMENTS
1	0.003	0.01	R-102	0.003	
2	0.005	0.01	1	0.005	Recheck step 1 until both points are calibrated.
3	0.008	0.01	2	0.008	
4	0.01	0.01	3	0.01	Repeat steps 1,2,3,&4.
5	0.001	0.001	GAIN(R-47)	0.001	Caution: Check PRESS TO BALANCE for minimum meter reading.
6	0.01	0.01	ADJ 0.01 (R-37)	0.01	Check linearity on this range and repeat steps 1 through 4, if necessary. Also check 5.
7	0.003	0.003	ADJ 0.003	0.003	0.001,0.003, and 0.01 volt ranges should now be calibrated.
8	0.01	0.03	0.03(R-21)	0.01	This adjustment is on top of the pre—amp housing.
9	0.015	0.03	4	0.015	Recheck step 8 until steps 8 and 9 are correct.
10	0.025	0.03	5	0.025	
11	0.03	0.03	6	0.03	Repeat steps 8 through 11.
12	0.03	0.1	0.1(R-19)	0.03	
13	0.05	0.1	7	0.05	
14	0.09	0.1	8	0.09	Recheck steps 12 and 13 until steps 12,13, and 14 are correct.
15	0.1	0.3	0.3(R-17)	0.1	
16	0.25	0.3	9	0.25	Recheck step 15 until steps 15 and 16 are correct.
17	0.3	1.0	1.0(R-15)	0.3	
18	0.9	1.0	10	0.9	Recheck step 17 until steps 17 and 18 are correct.
19	1.0	3.0	3.0(R-13)	1.0	
20	2.5	3.0	11	2.5	Recheck step 19 until steps 19 and 20 are correct.

WARRANTY

Boonton ELECTRONICS Corporation guarantees to the original purchaser that each instrument it manufactures be free from defects in material and workmanship for a period of one year after date of initial shipment. Our liability is limited to repairing or replacing any defective part with the exception of vacuum tubes, panel lamps, fuses, and batteries. The warranty lapses if, upon our examination, we judge that the instrument has been abused in any way.

PROCEDURE TO FOLLOW IF INSTRUMENT IS DEFECTIVE

1. Call our plant or our representative nearest you. A simple solution may result from discussion of the problem with our trained personnel.
2. If the fault is not readily eliminated, prepare the instrument for return to us. Pack carefully in a sturdy container using several inches of shock absorbing material on all six sides of the instrument. Include all probes, cables, or accessory units. On all paper work pertaining to the returned instrument, note the model and serial number and state briefly the details of the fault. Ship to us transportation charges prepaid.
3. If the instrument is within the warranty, we will repair and return to you transportation charges prepaid. If the instrument is beyond the one year warranty period, we will repair and return it unless approval on a cost estimate is requested. If the instrument is within the one year warranty period, but our examination reveals abuse, we will await approval of our cost estimate before proceeding with repairs.

TABLE 2

VOLTAGE MEASUREMENTS

PIN	1	2	3	4	5	6	7	8	9	
V 1 BEC 525001	85V	0V	0.75V	-4.3V	-4.3V	60V	0V	0.4V	0V	DC
V 2 12AX7	85V	0V	0.25V	-8.6V	-8.6V	70V	0V	0.3V	-4.3V	DC
V 3 7199	350V	100-150V	80V		6.0V	2.0V	0V	200V		DC AC
V 4 12AT7	320V	-2.1V	1.8V			320V	-0.2V	4.0V	6.0V	DC AC
V 5 6X4	325V			6.0V		325V	360V			DC AC
V 6 OA2	150V	0V		0V	150V		0V			DC

CONDITIONS:

(1) DC Voltage Measurements with vacuum tube voltmeter (BEC 95A)

(2) AC Voltage Measurements with vacuum tube voltmeter (Ballantine 314)

(3) 117V 60 cycles line input.

(4) All measurements to chassis.

(5) Input 10 mv at (300 Kc).

91D
a

TABLE 3

D.C. RESISTANCE TO GROUND

PIN #	1	2	3	4	5	6	7	8	9
V1 BEC 525,001		6.8M	6.8K				2.2M	6.8K	
V2 12AX7		1M	470				1M	1.2K	
V3 7199			90K			1.2K	1M	20K	1M
V4 12AT7		2-3K	3-4K				50K-75K	4-5K	
V5 6X4	1K					1K			
V6 OA2		0		0			0		

D.C. Resistance Measurements with Simpson 260 (polarity +)

91D
a

TABLE 4

D.C. RESISTANCE TO CATHODE OF 6X4 RECTIFIER (PIN 7)

PIN #	1	2	3	4	5	6	7	8	9
V1 BEC 525,001	1M					500K			
V2 12AX7	120K					330K			
V3 7199	1K	180K	68K						
V4 12AT7	1K					1K			
V6 OA2	8.5K				8.5K				

D.C. Resistance Measurements with Simpson 260 (polarity +)

TABLE OF REPLACEABLE PARTS

Reference	Description					BEC Part No.
C1	Capacitor,	Mylar	0.1	µf	200V	230,116
C2	"	Mylar	0.1	µf	200V	230,116
C3	"	Mylar	0.1	µf	200V	230,116
C4	"	Mylar	0.1	µf	200V	230,116
C5	"	Mylar	0.0033	µf	200V	230,119
C6	"	Mylar	0.0033	µf	200V	230,119
C7	"	Mylar	0.005	µf	200V	230,121
C8	"	Mylar	0.001	µf	200V	234,018
C9	"	Mylar	0.015	µf	200V	230,102
C10	"	Elect.	50	µf	6V	283,112
C11	"	Met. P.	1.0	µf	200V	230,104
C12	"	Mylar	0.01	µf	200V	230,120
C13	"	Mylar	0.01	µf	200V	230,120
C14 thru 17		(not used)				
C18	"	Mylar	0.022	µf	200V	230,101
C19	"	Met. P.	1.0	µf	200V	230,104
C20	"	Elect.	50	µf	6V	283,112
C21	"	Mylar	0.1	µf	400V	230,124
C22	"	Mylar	0.05	µf	200V	234,016
C23	"	Mylar	0.047	µf	200V	234,002
C24	"	Mylar	0.002	µf	200V	234,000
C25	"	Mylar	0.033	µf	200V	234,001
C26	"	Mylar	0.033	µf	200V	234,001
C27	"	Mylar	0.022	µf	200V	230,101
C28	"	Elect.	4	µf	450V	283,135
C29	"	Mylar	0.01	µf	200V	230,120
C30	"	Elect.	4	µf	450V	283,135
C31	"	Met. P.	1.0	µf	200V	230,104

Reference		Description			BEC Part No.
C32	Capacitor, Elect.	4.0	µf	250V	283,136
C33	" Elect.	20-20	µf	150V	283,138
C34	" Mylar	0.05	µf	200V	234,016
C35	" Mylar	0.1	µf	200V	230,116
C36	(not used)				
C37	" Mylar	0.022	µf	200V	230,101
C38 thru 40	(not used)				
C41A,B,C,	" Elect.	20-20-20	µf	450V	283,113
C42	" Elect.	1000	µf	15V	283,101
C43	" Elect.	200	µf	15V	283,118
Ch-1	Chopper	BBM-Special			540,108
CR-1	Rectifier, Sel.	Sarkes Tarzian #304B			532,001
D1	Diode	1N600			530,008
D2	"	1N600			530,008
D3	(not used)				
D4	Diode Stabistor	STC 135			530,009
D5	Diode Zener	1N1775			530,026
D6	Diode Stabistor	STC 135			530,009
D7	Diode Stabistor	STC 135			530,009
D8	Diode Stabistor	STC 135			530,009
D9	Diode	Special			530,025
F1	Fuse	AGC 1.0 Amp.			545,500
I1	Lamp	GE #323		3V	545,106
I2	Lamp	GE #323		3V	545,106
M1	Meter	Special 0-200 µa			554,136

Reference		Description			BEC Part No.
R1	Resistor, Comp.	22 M	1/2W	5%	301,191
R2	" Var.	50 K	2W	20%	311,168
R3	" Comp.	8.2 K	1/2W	5%	301,109
R4	" Comp.	330 K	1/2W	5%	301,147
R5	" Comp.	330 K	1/2W	5%	301,147
R6	" Comp.	22 M	1/2W	5%	301,191
R7	" Comp.	150 K	1/2W	5%	301,139
R8	" Comp.	8.2 K	1/2W	5%	301,109
R9	" Comp.	390 K	1/2W	5%	301,149
R10	" Comp.	100	1/2W	5%	301,063
R11	" Comp.	2.2 K	1/2W	5%	301,095
R12	" Dep. Car.	675Ω	1/2W	1%	306,695
R13	" Var.	1 K	1/10W	10%	311,119
R14	" (not used)				
R15	" Var.	2.5 K	1/10W	10%	311,128
R16	(not used)				
R17	" Var.	25 K	1/10W	10%	311,159
R18	(not used)				
R19	" Var.	100 K	1/10W	10%	311,121
R20	" Comp.	360 K	1/2W	5%	301,148
R21	" Var.	250 K	1/10W	10%	311,122
R22	" Dep. Car.	5 M	1/2W	1%	306,693
R23	" Comp.	6.8 M	1/2W	5%	301,179
R24	" Met. Film	6.8 K	1/2W	5%	315,012
R25	" Comp.	1 M	1/2W	5%	301,159
R26	" Met. Film	470 K	1W	5%	315,010
R27	" Met. Film	330 K	1W	5%	315,013
R28	" Comp.	470 K	1/2W	5%	301,151
R29	" Comp.	2.2 M	1/2W	5%	301,167
R30	" Met. Film	6.8 K	1/2W	5%	315,012
R31	" Comp.	470 K	1/2W	5%	301,151
R32	" Var.	25 K	2W	10%	311,171

Reference		Description	BEC Part No.
R33	Resistor, Met. Film	82K 1/2W 5%	315,007
R34	" Met. Film	2.7K 1/2W 5%	315,001
R35	" Comp.	1.5M 1/2W 5%	301,163
R36	" Var.	250K 2W 5%	311,157
R37	" Var.	10K 2W 10%	311,154
R38 thru 41	(not used)		
R42	" Comp.	1M 1/2W 5%	301,159
R43	" Comp.	330K 1/2W 5%	301,147
R44	" Met. Film	1.2K 1/2W 5%	315,016
R45	" Comp.	100K 1/2W 5%	301,135
R46	" Comp.	1M 1/2W 5%	301,159
R47	" Var.	1M 2W 10%	311,158
R48	" Comp.	120K 1/2W 5%	301,137
R49	" Comp.	470Ω 1/2W 5%	315,017
R50	" (not used)		
R51	" Met. Film	200K 1W 5%	315,019
R52	" Met. Film	200K 1W 5%	315,019
R53	" Comp.	560K 1/2W 5%	301,153
R54	" Met. Film	20K 1/2W 5%	315,018
R55	" Comp.	1M 1/2W 5%	301,159
R56	" Comp.	22K 1/2W 5%	301,119
R57	" Comp.	1K 1/2W 5%	301,087
R58	" Comp.	180K 1/2W 5%	301,141
R59	" Comp.	1.2K 1/2W 5%	301,089
R60	" Comp.	68K 1/2W 5%	301,131
R61	" Comp.	1M 1/2W 5%	301,159
R62	" Comp.	220Ω 1/2W 5%	301,071
R63	" W.W.	20K 10W 5%	312,106
R64	" Comp.	33K 1/2W 5%	301,123
R65	" Comp.	33K 1/2W 5%	301,123
R66	" Comp.	120K 1/2W 5%	301,137

Reference		Description				BEC Part No.
R67	Resistor, Dep. Car.	4.22	K	1/4W	1%	305,314
R68	(not used)					
R69	" Comp.	1	M	1/2W	5%	301,159
R70	(not used)					
R71	" Comp.	2.7	K	1/2W	5%	301,097
R72	" Comp.	3.3	K	1/2W	5%	301,099
R73	(not used)					
R74	" Comp.	51	K	1/2W	5%	301,128
R75 thru 79	(not used)					
R80	" Comp.	1	MΩ	1W	20%	302,128
R81	" W.W.	1	K	5W	5%	312,104
R82	" W.W.	7.5	K	20W	5%	312,107
R83	" Var.	50Ω		2W	20%	311,175
R84	" Var.	15	K	2W	20%	311,109
R85	" Var.	10	K	2W	20%	311,102
R86	" Var.	10	K	2W	20%	311,102
R87	" Var.	10	K	2W	20%	311,102
R88	" Var.	10	K	2W	20%	311,102
R89	" Var.	10	K	2W	20%	311,102
R90	" Var.	10	K	2W	20%	311,102
R91	" Var.	10	K	2W	20%	311,102
R92	" Var.	15	K	2W	20%	311,109
R93	" Var.	15	K	2W	20%	311,109
R94	" Var.	25	K	2W	20%	311,115
R95	" Comp.	470	K	1/2W	5%	301,151
R96	" Comp.	2.2	M	1/2W	5%	301,167
R97	(not used)					
R98	" Dep. Car.	1.78	K	1/4W	1%	305,269
R99	" Dep. Car.	3.48	K	1/4W	1%	305,304
R100	" Dep. Car.	1.54	K	1/4W	1%	305,262

Reference		Description				BEC Part No.
R101	Resistor, Dep. Car.	1.47	K	1/4W	1%	305,259
R102	" Var.	2	M	1/10W	10%	311,176
R103	" Comp.	3.9	K	1/2W	5%	301,101
R104	" Comp.	2.2	M	1/2W	5%	301,167
R105	" Comp.	150	K	1/2W	5%	301,139
R106	" Comp.	470Ω		1/2W	5%	301,079
R107	" Comp.	680Ω		1/2W	5%	301,083
S1	Switch	2 Pole, 8 pos. Special				466,139
S2	"	5 Pole, 8 pos. Special				466,140
S3	"	SPST Carling #110-63				465,105
S4	"	Momentary Make				P/O 311,168
T1	Transformer	Power, Special				446,016
V1	Electron Tube	12AX7, Special				525,001
V2	"	12AX7				526,12AX7
V3	"	7199				526,7199
V4	"	12AT7, Special				525,002
V5	"	6X4				526,6X4
V6	"	OA2				526,OA2
Q1	Transistor	2N554				528,003

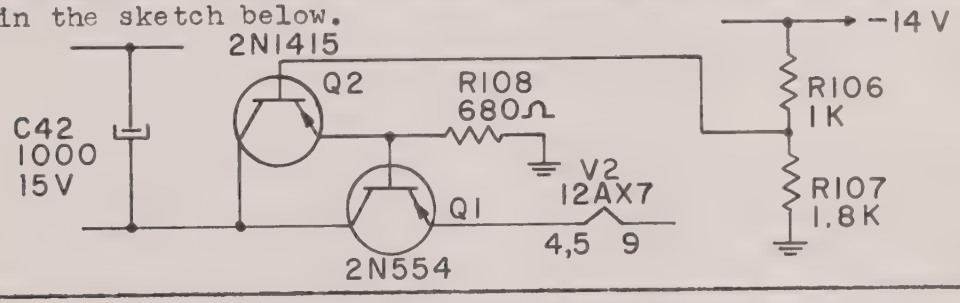
INSTRUCTION BOOK ADDENDUM

MODEL 91D

RF VOLTMETER

Change No. New Data for Schematic

1. Change value of R23 to 22M.
2. Change value of R43 to 200K.
3. Change value of R45 to 180K.
4. Change value of R48 to 68K.
5. Change value of R58 to 360K.
6. Change value of R60 to 820K. Change upper connection of R60 from the +150 V bus to the junction of R58 and R57.
7. Change value of R106 to 1.5K.
8. Change value of R107 to 1.8K.
9. Omit capacitor C21.
10. Change the plate and screen supply for the 7199 from +360 V to +330 V.
11. Add Q2 and R108 to the heater regulator circuit as shown in the sketch below.



New Data for Parts List

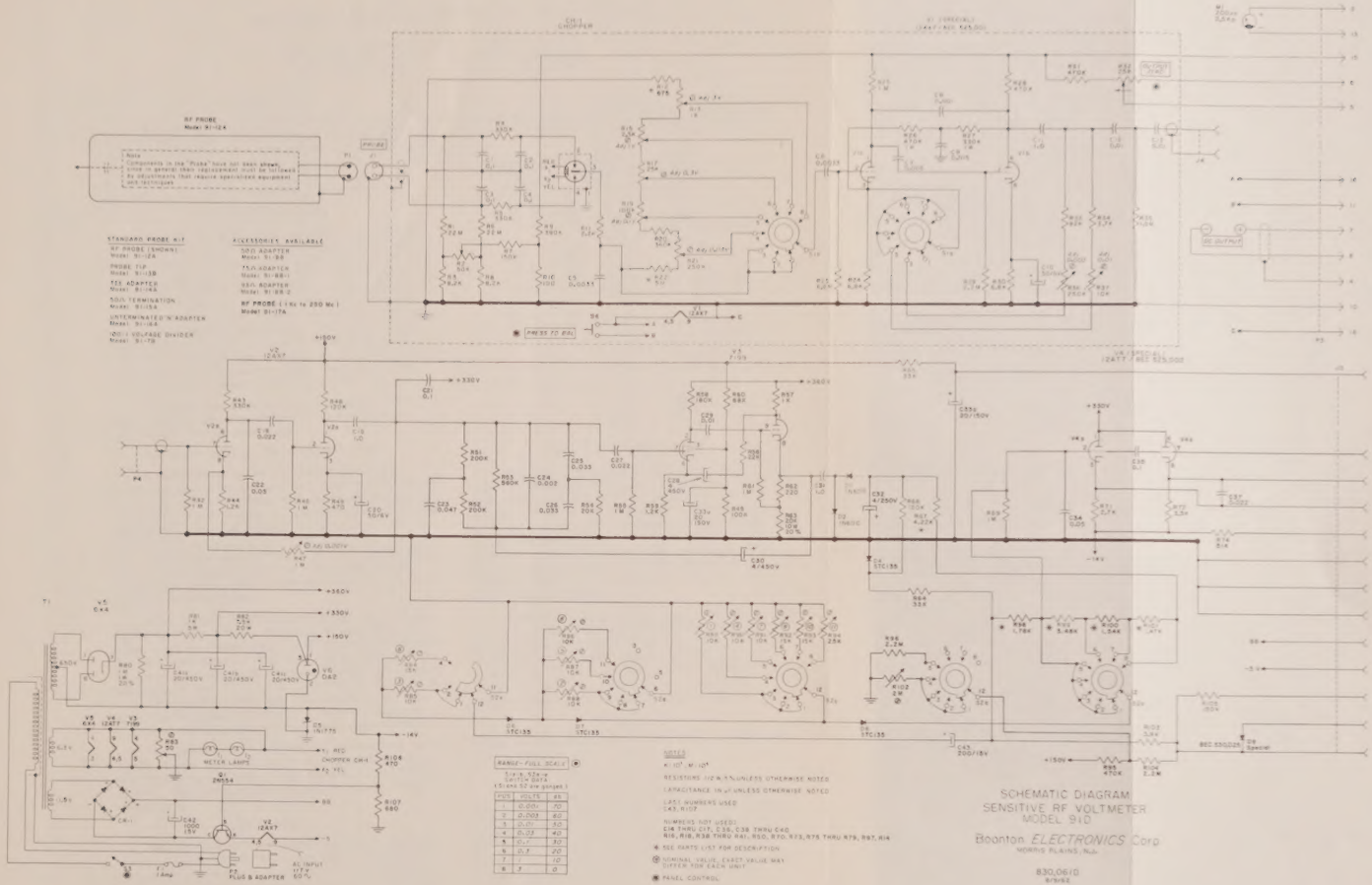
Reference		Description	BEC Part No.
R23	Resistor, Comp.	22M 1/2W 5%	301,191
R43	" "	200K " "	301,142
R45	" "	180K " "	301,141
R48	" "	68K " "	301,131
R58	" "	360K " "	301,148
R60	" "	820K " "	301,157
R106	" "	1.5K " "	301,091
R107	" "	1.8K " "	301,093
R108	" "	680Ω " "	301,083
Q2	Transistor,	Germanium, PNP 2N1415	528,002

New Data for Section 5

5.5.2 c Substitute .001 for "(GAIN)"

Fig. 5 Designate minature potentiometer on top terminal board as R102.

Table 1, Step 5 Add .001 under "GAIN (R-47)"


RF PROBE
Model 91-124
STANDARD PROBE KIT
RF PROBE (SHOWN)
Model 91-124
PROBE TIP
Model 91-133
ACCESSORIES AVAILABLE
50Ω ADAPTER
Model 91-88
75Ω ADAPTER
Model 91-88-1
93Ω ADAPTER
Model 91-88-2
50Ω TERMINATION
Model 91-134
UNTERMINATED N ADAPTER
Model 91-164
100:1 VOLTAGE DIVIDER
Model 91-178
RF PROBE (1 Hz to 250 Mc)
Model 91-174
CH-1 CHOPPER
PRESS TO BAL
+150V
+330V
+360V
-14V
METER LAMPS
CHOPPER CH-1
AC INPUT
117 V
60 ~
FUSE
1 Amp
PLUG & ADAPTER
RANGE-FULL SCALE
5 m-v, 15 m-v
50 m-v, 150 m-v
(5 scale 50 div gauges)
POS
VOLTS
AS
0.005
70
0.003
60
0.01
50
0.03
40
0.1
30
0.3
20
1
10
3
0
NOTES
K=10³, M=10⁶
RESISTORS 1/2 W ±5% UNLESS OTHERWISE NOTED
CAPACITANCE IN μF UNLESS OTHERWISE NOTED
LAST NUMBERS USED
C49, R107
NUMBERS NOT USED
C19 THRU C17, C35, C38 THRU C40
R19, R18, R38 THRU R41, R50, R70, R73, R75 THRU R79, R87, R114
SEE PARTS LIST FOR DESCRIPTION
NOMINAL VALUE, EXACT VALUE MAY DIFFER FOR EACH UNIT
PANEL CONTROL
SCHEMATIC DIAGRAM
SENSITIVE RF VOLTMETER
MODEL 910
Boonton ELECTRONICS Corp
MORRIS PLAINS, N.J.
830,0610
8/9/62

HIGH-FREQUENCY MEASUREMENT OF MULTILAYER CERAMIC CAPACITORS

Raymond E. Lafferty
Boonton Electronics
Parsippany, N.J.

John P. Maher
Sprague Electric
North Adams, MA

INTRODUCTION

Many circuit functions in high-frequency applications will suffer, either in performance or efficiency, without the use of low-loss capacitors. Until recently it was not possible to measure the loss of capacitors having high Q-factors at frequencies above about 100 MHz.

MEASUREMENT PROBLEMS

Attempts at measuring low-loss capacitors at high frequencies with admittance or impedance bridges, Q-meters, and especially with S-parameter measurements have been generally unsuccessful because of imperfect instrument components, and/or the extreme resolution needed to separate the minor (loss) parameter from the major (quadrature) parameter. The difficulty stems from a need to evaluate accurately the difference between two quantities of nearly equal value, with an uncertainty that approaches and sometimes exceeds that difference.

Measurements made with a disregard for these factors produce positive and negative results of random magnitude.

RESONANT COAXIAL TRANSMISSION-LINE

A resonant coaxial transmission-line, short-circuited at one end and open-circuited at the other, whose fundamental resonant frequency and Q-factor are known, is perturbed with a test capacitor connected either in series at the shorted end of the line, or in shunt at the open end. Measuring the Q-factor of the system with the Δf technique yields the effective series resistance (esr), capacitance, and the Q-factor of the test specimen.

This method of measurement has the advantage that there are no adjustable elements to alter circuit conditions in an unprescribed way, the only variable is the frequency which can be measured with an uncertainty of less than 1 ppm, the loss of the line as a function of frequency is quite predictable, and the Q-factor of the line can be made sufficiently high to support accurate measurements of low-loss capacitors.

The practical use of this fundamental technique is now feasible with the benefit of modern signal generators, sensitive r.f. millivoltmeters, and programmable calculators or small computers.

FREQUENCY

The measurement frequencies are a function of the length of the line and the effective capacitance of the test capacitor. The following table shows the relationship between frequency and capacitance for both series and shunt mode measurements for the Model 34A Resonant Line.

SHUNT RANGE (pF)	FREQUENCY RANGE (MHz)		SERIES RANGE (pF)	
200 to 0	25 to 130	130 to 250	> 1000 to 1.0	(1/4) λ
100 to 0	265 to 390	390 to 500	> 1000 to 1.0	(3/4)λ
30 to 0	530 to 650	650 to 750	> 1000 to 1.0	(5/4)λ
		910 to 1000	> 1000 to 1.0	(7/4)λ
		1170 to 1250	> 1000 to 1.0	(9/4)λ

METHOD OF MEASUREMENT

The measurement of a capacitor requires only the measurement of two frequencies, one on each side of the resonant response at a predetermined ratio of resonant to off-resonant voltage. These two frequencies are entered in a programmed calculator in which the fundamental resonant frequency and the Q-factor of the line have been stored, and the measurement frequency, esr, capacitance, and Q-factor of the capacitor are obtained.

The precision of the measurement is in the order of ±1%. The reproducibility (one system to another) is generally within ±10%. The accuracy of the system, without benefit of NBS standards, has been calculated as being between 7 and 20 percent, for Q-factors of 100 to 10000, respectively. The specified accuracy is,

$$\pm(5 + Q^{0.35})\%$$

which is approximately 50 percent greater than calculated.

MEASUREMENT SYSTEM

The components of the system consist of a stable signal generator with a digital readout of frequency of 6 or 7 digits, a sensitive r.f. millivoltmeter which is normally used on the 3 mV range, the resonant coaxial transmission-line, and a programmable calculator. The equipment, without the calculator, is in Fig. 1.

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